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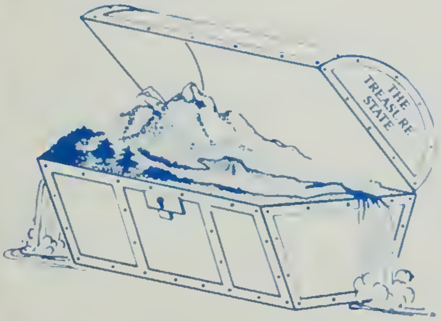

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Final Summary Submitted to
The Montana Water Resources Center
Montana State University
Bozeman, Montana

1986

The research on which this report is based was supported in part by funds provided by the United States Department of the Interior - U. S. Geological Survey, through the Montana Water Resources Institute as authorized under the Water Resources Research Act of 1984 (PL 98-242) as amended by Public Law 101-397.

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OVERBURDEN SOIL PASTE: A SOLUTION OR A PROBLEM

by

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May, 1986

The work upon which this report is based was funded by the Montana Water Resources Research Center, Montana State University (IRS No. 81-600-1254); Proposal by, Frank A. Abercrombie (Deceased).

1. INTRODUCTION

One of the most important strip mining impacts in semi-arid areas such as Eastern Montana is the effect of the mining process upon the water quality of the ground water aquifers. The strip mining process of removing the overburden (mine spoils) destroys the original aquifer associated with the coal seam. The coal aquifer is slowly reestablished within the new cast overburden zone; however, soluble salts in this overburden will be dissolved into the ground water increasing the total dissolved solids (TDS) possibly until mineral saturation occurs. The increasing TDS continually degrades the water quality and in some instances even renders the water unfit for irrigation or livestock.(Abercombie, F. N., 1985).

The use of saturated-paste extract analyses to predict post-mining ground-water quality has become common practice in the Northern Great Plains. The analyses, performed on coal overburden in proposed mine areas, are required under State and Federal regulations to determine reclaim-ability of post-mining landscapes. These data are primarily intended for revegetative planning but also become useful in hydrology. Perhaps more dependable techniques of determining soluble salt content for hydro-geological purposes include batch-mixing analyses and column leach tests, but these methods are far more time consuming and manpower intense. (VanVoast, W.A. and others, 1978, 1986; Harrington, A. H. 1984).

These techniques, thus far hydrologically applied only to coal mining situations, should also have value in predicting water quality changes at proposed metal mines. These soils are naturally richer in trace metals and may also contain material originating from a mineralized zone.

The increasing hydrogeologic application of a methodology developed for other purposes warrants some scrutiny to better mesure its applicability. Objectives of this study are to examine some of the procedures of preparing pastes and extracts, comparing analytical results from the different procedures, and recommending procedural improvements where warranted. Specifically, vacuum extraction, pressure extraction, and centrifuge extraction techniques and results are compared. Because of the extensive use of soil paste analysis; any saving of time and effort, and thua money, in the procedure would be significant. Any alternate method must yield results comparable to those by the standard method.

Accurate predictive estimates cannot be made without accurate analyses. The accurate analyses must be performed on extracts which are representative and reproducable. Without meaningful extract, the concept "garbage in, garbage out" takes over.

The soil paste extract preparation described in "U.S.D.A. Handbook No. 60" seems simple. The analysis of soil paste extracts is accomplished by mixing sieved overburden soil and deionized water, equilibrating, filtering the mixture and analyzing the filtrate for dissolved ions.

Many of the weaknesses of the procedure have been addressed by others. The recommended corrective actions usually treated the symptoms and not the cause:

1. Instructions on the preparation of saturated pastes are open to a wide range of individual interpretation.

2. Richards (1949) recommends the use of sodium hexametaphosphate to prevent precipitation of calcium carbonate; however, neither sodium nor phosphate can be determined from this sample. Precipitation only occurs if the solution becomes supersaturated.

3. Jacober and Sandoval (1970) suggested that the composition of the extract is dependent upon the level of vacuum and the incremental portion of the extraction.

4. Van Voast (1982) has shown that at least some soil paste extract analyses are in error. The sulfate anion equivalents exceeded the total cation equivalents; the rule of electroneutrality should exist.

5. Abercrombie (1985) observed filtrate evaporation during vacuum filteration. This evaporation increases the dissolved solids content of the filtrate (extract); therefore, the chemical analysis data did not accurately characterize the original chemical composition of the soil paste extract.

2. SAMPLE PREPARATION-SOIL PASTE

Soils sample splits from earlier research studies by from Mr. Wayne Van Voast and were used. These spoils samples were collected in 1982 from pits at three Eastern-Montana mines. Those with the prefix "WD" were obtained at West Decker mine; those with the prefix "E" are from area E at the Rosebud mines; the prefix "BS" identifies a sample from the Big Sky mine. All samples were newly cast overburden collected near the bases of the mine pits. Collection locations were carefully recorded so that, following reclamation, research wells could be installed to compare spoils-water quality with past-extract quality. Results of that work are still pending resaturation at the sample sites.

Soil samples were air dried for 48 hours before and after passing through a screen with 2mm square openings. Well mixed soil samples of between 1000 grams and 1500 grams were saturated with deionized water in large glass beakers and mixed with a stainless steel spatula. All weights and volumes were recorded.

The following saturated paste description, as given in "USDA Handbook No. 60", was used to determine if more dry soil or more deionized water should be added to the experimental paste:

> At saturation the soil paste glistens as it reflects light, flows slightly when the container is tipped, and slides freely and cleanly off the spatula for all soils but those with a high clay content. Free water should not collect on the soil surface, nor should the paste stiffen markedly or lose its glistening appearance on standing (Richards, L.A., 1969). An equilibration time of at least 16 hours was used.

A variation of 10% in the total deionized water used during saturated soil paste preparation had a marked effect on the appearance of that paste. It took only a few minutes to prepare the paste. No adjustments were needed to maintain appearance of paste after the initial 4 hours. An equilibration time of at least 16 hours was used.

These saturated soil pastes were used as common sources for comparative extractions by vacuum, pressure, and centrifuge. When additional soil paste was needed, the soil-to-water ratio was maintained.

3. SAMPLE PREPARATION-VACCUM EXTRACT

Approximately 150 milliliters of paste was transferred to each of two filter funnels, which filled the available space in the funnels. Moisture traps - cold fingers cooled by liquid nitrogen - were installed down stream from filter flasks to capture any water vapor. A common vacuum of 60 centibars (cb) was applied until extraction nearly stopped. Filtration was stopped before air passed through filter cake. Solution volumes and filtering times were recorded.

The moisture trap solutions, if any, were transferred to small plastic test tubes, acidified to 1% acid with HNO_3, and capped.

The extract was hand pressure filtered through a 0.45um "Millipore VC"(1) filter into two plastic test tubes. One was acidified to 1% acid with HNO3. Portions of both samples were diluted 1:10 with deionized water while maintaining a 1% HNO3 in the dilution of the acidified sample.

Vacuum filtering of paste from soils WD-1 and E2-A was discontinued after 6 hours and 8 hours respectively even though saturated soil paste remained on top of the filter cakes.

4. SAMPLE PREPARATION-PRESSURE EXTRACT

Approximately 150 ml of paste was transferred into a PVC cylinder. This cylinder had a "Watman" GF/C filter at one end and a pipe fitting at the other. The cylinder and sample were supported with the filter end down and 80 psi compressed air applied to the other end. Filtration was stopped before air passed through the filter cake. The pressure filter extract was handled the same way as the vacuum filter extract.

Saturated soil paste remained on top of filter cakes for all pastes. Paste from soil E-2A would not pressure filter so no extract was obtained. This method cannot be used for soils with a high clay content; however, the data were of value for comparison with the other methods.

5. SAMPLE PREPARATION-CENTIFUGE EXTRACT

Approximately 150 ml of paste was transferred into four plastic centrifuge tubes and capped. Samples were centrifuged for fifteen (15) minutes at 1000 RCF (relative centrifugal force) which is the ratio of the acceleration in the centrifuge to the acceleration of gravity. The centrifuged extract was handled the same way as the vacuum filter extract.

Extraction by centrifuge from soil paste E-2A was inefficient; because after centrifuging, the extract would reabsorb back into the paste. The top halves of the centrifuged paste were combined and recentrifuged to obtain a usable volume of extract.

(1) Company names and models are given for the readers' benefit, and do not imply endorsement or preferential treatment by the Montana Bureau of Mines and Geology

6. SAMPLE PREPARATION -ADDITIONAL EXTRACTS

After the original extracts had been prepared and analyzed, procedural questions arose. To help clarify possible problems, the following extracts were prepared and analyzed:

1. Vacuum extract from paste equilibrated for 2 hours and 4 hours.
2. Centrifuge extract from paste equilibrated for 4 hours.
3. Vacuum extract using vacuum of 80 cb.
4. Vacuum extract from resaturated soil paste which was previously vacuum extracted.
5. Centrifuge extract from resaturated soil paste which was previously centrifuge extracted.
6. Centrifuge extract using 8000 RCF.

7. SAMPLE ANALYSIS

The unacidified extract was used for specific conductance, pH, and SiO2 analysis. The unacidified diluted extract was used for alkalinity analysis and for anion analysis by "Dionex Model 12" anion chromatograph interfaced to a "Spectra Physics 4100" computing intergrator. The acidified extract and the diluted acidifed extract were used for major and trace cation analysis by "Applied Research Laboratories 3400" induction coupled argon plasma emission spectrometer. The detailed listing of the analytical results are found on Table 1.

DISCUSSION

It is important that the volume of water used to saturate the soil be recorded. If this is not done, then the saturation percentage should be determined by Agriculture Handbook 60, Method 27. The preparation of soil paste is not an exact procedure. Variations of 5 to 20% of the water used can occur, depending on an individual's estimation of saturation. By reporting chemical concentrations in meq/100 grams soil (mg/L x L/100g - g/equivalent wt) the errors introduced because of differences in volume of water used to saturate soil paste are minimized. As an example, calculations of centrifuge data from first and second saturation of soil WD-1 give:

	1st & 2nd Weighted Average	1st Saturation	% Difference
meq Na/L	17.2	18.2	5.5
meq Na/100g	2.10	2.05	2.4
meq S04/L	11.2	12.5	10.4
meq S04/100g	1.37	1.42	3.5

This is not an exact comparison of the effect of 7.6% extra water (1700 ml of water for 1st saturation and 130 ml of water to resaturate). The removed extract from the first saturated paste was not in equilibrium with the solution in the second saturation.

The reduction of varibility of data reported as meq/100 gram needs to be confirmed using several different soil types.

It should be noted that agreement with extraction values reported by the private commercial lab was much better when values were reported in meq/100 grams soil. A reference to table 3 and table 7 illustrates this very clearly.

The saturated soil paste equilibration time of 4 hours was sufficient for E-5C. Please refer to table 2 and compare values of soil E-5 paste using 2,4,and 16 hours equilibration time. This may or may not be true for all soil types. If air drying of paste is minimized, and time restraints allow, it would be preferable to equilibrate for 16 hours.

If vacuum extraction is used, the volume of water in the vapor trap must be measured and appropriate calulation corrections made, or must be combined with the extract. Analysis of moisture trap water for major and trace cations indicates that these solutions are essentially deionized water. The most practical routine method to verify this condition would be to analyze trapped water for specific conductance. The loss of this water has a concentrating effect on the extract. An error of as much as 15% could result in values for slow filtering pastes from soils similar to E-2A. The corrective factor for this sample was: 15 ml (extract) - 16.1 ml (extract + trap) = .870. A larger correction factor would result if vacuums greater than the 60 cb required by Handbook No. 60 are used.

The chemical parameters of the extract do not appear to be dependent upon the level of vacuum used for extraction. Please see table 2. This conclusion is contraty to that published by F. Jacober and F. Sandoval (1970). Had they captured water vapor from vacuum filtering, their conclusion may have been different.

Pressure filtering yields an extract with comparable major ions to those from vacuum filtering. See Figure 2. This techique has difficulties. The process is slow and labor intensive, extract recovery is low, and a compressed gas source is needed. There also appear to be problems with some constituents, especially SiO2, B, Cu, Ti, and Zn.

The use of a centrifuge to obtain an extract also gives comparable results. See Table 2. In fact there are several advantages of centrifuge extraction over vacuum filtering. The equipment set-up is simpler, no vacuum pump, vacuum regulator, large filters, or cold vapor trap are required. Accurate volume measurement is not necessary, and there is less chance of contamination because only the plastic centrifuge tubes are reused. The extract was clearer and easier to pressure filter through a .45mm finishing filter. There was a substantial savings in time since centrifuging takes about one-fourth the total time and one-third the actual operator's time to extract one sample. See Min/sample column given on Table 5. The saving in time, and therefore money, was even greater when several soil paste samples were extracted. Field extracton by hand (or power take-off) cenrifuge would be possible. The composition of the extract did not depend on centrifugal force applied. Refer to sample WD-1 at 1000 RCF and 8000 RCF on Table 2.

Sandoval (1979) reported poor agreement between labs in particle size and fair agreement in % saturation determinations. He suggested that most laboratories need to reevaluate their procedures and techniques. Results shown on table 6 confirm his conclusions.

Because only small amounts of extracts were saved for specific conductance (s.c.) and pH, a low confidence level should be given them. Wayne Van Voast (1982) estimates that the S.C. of saturated paste extract should approximately equal the S.C. of the effluent at the .5 pore volume in column tests. Specific conductances obtained for BS-1C and BS-3 compare well with his estimates.

	BS-1C	BS-3
calculated by Van Voast at 0.5 pore volume	4120	3220
graph reading from data points in vicinity of 0.5 pore volume	3800	3700
soil paste extract	3660	3580

Erratic results for duplicates were obtained in the analysis of trace levels of Fe, Si02, Al, and Zn. Incomplete filtering of fine clay particles would contribute to this variation. The filter papers used in vacuum filtering contain some leachable Fe and Zn. These filter papers are about 4 inches in diameter and sometimes the volume of extract is small. If the filter paper is not known to be "clean", then it should be washed with dilute HN03, well rinsed, and dried. It is not known why Cu was slightly higher in vacuum extracts.

Trace metals such as B, Cr, Cu, Li, Mo, Sr, and V showed distinctive anomolies for the various soil types. Since the soils were from Eastern Montana coal mining overburden, this was somewhat unexpected. Had the soils come from overburden in metal mining operations, these anomolies probably would have been more pronounced, and it is reasonable to assue that anomolies of other trace metal would also have been significant.

If the vacuum extract is corrected for water in the moisture trap, the average % relative standard deviation for centrifuge extract is slightly less (refer to table 4). In both instances, the average % relative standard deviation is very good. Standard deviation is a stastical value derived by comparing replicate analysis. Simply put, it is an estimate of the range of values that an additional analysis will fall 95% of the time. By dividing the standard deviation by the average value, the % relative standard deviation is obtained. As an example, an analysis of past extract of soil B5-1C for calcium would be 0.65 + .003 meq/100g 95 time out of 100 tries.

9. SUMMARY

For data submitted to the Montana Water Resource Research Center, using extracts for estimating impact of overburden relocation impact in Montana, the saturated soil paste preparation and extraction presently given in the"USDA Handbook No. 60" should be ammended:

1. Measure water added to soil to prepare a paste or analysis for % saturation. Report concentrations in the units of meq/100 grams of soil or ueq/100 grams of soil.

2. Equilibrate soil paste for 4 hours or longer (overnight if possible).

3. Use centrifuge as alternate method of extraction.

4. Vacuum extraction should use "clean" filter paper if trace elemements are to be determined.

5. Capture water vapor and reintroduction into sample if vacuum extraction is used.

6. Eliminate the use of sodium hexametaphosphate if analytical procedure for Calcium allows use of 1% HNO3 in sample matrix.

Differences in trace metal concentrations in paste extracts of trhe spoil soils from coal mining overburden were delineated.

Extracts of soil paste studies should be analyzed for as many parameters as practical. The effects of cast overburden relocation on trace metal concentrations of groundwater are not widely studied. Areas of environmental concern might well be going unnoticed.

Analysis of soil paste centrifuge extracts for trace metals might be an effective tool for some mineral exploration. This could be used in place of, or in addition to, more conventional geochemical methods.

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REFERENCE TABLES

TABLE 1 – TABULATION OF ANALYTICAL RESULTS

Code	Method *	Sc	Ph	Ca**	Mg**	Na**	K**	Fe**	Mn**	SiO2**	Al***	Ag***	B***	Cd***	Cr***
8S-1C	V	3688	7.96	362	282	154	21.6	.22	.059	9.9	140	<2	328	2	3
	V	3834	7.87	363	282	155	22.1	.20	.060	10.6	120	<2	343	2	10
	P	3634	7.69	373	288	160	22.5	.015	.062	11.1	80	10	410	4	16
	C	3608	7.64	372	289	159	23.2	.009	.063	11.1	<30	5	340	3	9
	C	3637	7.74	370	288	157	23.2	.017	.065	11.3	140	21	370	8	21
WD-3	V	6303	8.11	349	116	1270	22.9	.29	1.08	15.1	90	<2	670	3	2
	V	6317	8.26	350	116	1290	23.4	.10	1.09	15.4	80	4	640	3	5
	P	6522	8.43	347	116	1300	27.3	.027	.51	17.4	<30	<2	909	<2	4
	C	6581	8.22	359	119	1299	24.2	.028	1.13	15.6	<30	<2	670	<2	<2
	C	6506	8.10	358	118	1297	23.9	.030	1.12	15.4	<30	<2	640	<2	<2
	C	6487	8.12	354	117	1301	24.2	.028	1.11	15.2	<30	<2	610	<2	<2
E-5C	V	4321	8.13	591	352	146	27.1	.13	.81	17.5	250	29	1730	12	24
	V	4460	8.22	592	355	144	26.8	.082	.81	18.0	190	32	1760	6	26
	V 4 HR 80 cb			595	351	156	28.0	.061	.048	11.6	60	<2	1410	<2	11
	P	4430	8.27	595	357	150	27.1	.047	.87	19.4	200	26	2050	10	26
	C	4453	8.24	600	357	149	28.4	.027	.84	18.0	280	46	1790	13	31
	C	4427	8.23	598	356	150	28.6	.035	.83	17.4	50	<2	1750	<2	12
	C	4478	7.87	606	356	151	28.0	.024	.82	18.2	130	22	1770	7	19
	C 2 HR			556	318	143	27.5	.22	.38	12.7	200	<2	1180	<2	9
	C 4 HR			592	350	157	31.0	.37	.49	14.2	490	<2	1470	<2	12
WD-4	V	3189	8.14	40.6	46.0	603	19.5	.15	.049	5.7	30	<2	130	<2	<2
	V	3218	8.13	45.0	46.0	614	19.2	.035	.053	6.2	<30	<2	180	<2	<2
	P	3296	8.68	38.1	44.4	612	19.1	<.002	.048	9.0	<30	<.2	340	<2	<2
	C	3174	8.66	38.6	45.8	613	19.9	.024	.038	5.7	40	<2	150	5	4
	C	3128	8.71	38.4	45.4	609	20.2	.055	.040	6.0	130	<2	140	<2	4
	C	3336	8.97	38.3	45.2	616	20.3	.099	.040	6.8	200	<2	160	<2	<2
WD-4D	V	3303	8.47	33.4	41.1	611	19.5	.060	.011	3.0	40	<2	40	<2	2
	V	3114	8.52	32.9	40.5	599	19.4	.048	.013	3.2	40	<2	40	<2	4
	C	3399	8.36	33.8	43.1	650	21.3	<.002	.008	3.4	<30	<2	40	<2	2
	C	3371	8.29	33.4	42.7	658	21.4	<.002	.007	3.3	<30	4	60	<2	<2
	C	3473	8.29	33.7	43.0	652	21.4	.006	.007	3.4	<30	12	60	<2	<2
WD-1	V	2239	8.31	8.8	5.9	391	8.2	1.36	.040	9.4	400	<2	40	<2	<2
	V	2167	8.34	8.0	5.8	424	8.8	.29	.012	5.7	750	<2	80	<2	<2
	P	2141	8.56	5.8	4.4	428	8.4	.14	.008	16.9	420	<2	520	<2	<2
	C	2005	8.49	6.7	6.0	422	9.3	.30	.008	9.7	1220	<2	30	2	<2
	C	2005	8.49	6.6	6.0	417	9.4	.30	.008	9.5	1230	<2	50	<2	<2
	C	2005	8.49	6.6	6.0	416	9.3	.30	.007	9.5	1250	<2	<20	<2	<2
	C 8000RCF	2005	8.49	6.6	6.0	414	9.3	.29	.008	9.6	1250	<2	<20	<2	<2
	C 8000RCF	2005	8.49	6.6	5.9	420	9.5	.29	.007	9.6	1250	<2	<20	<2	<2
WD-1(2)	V	1832	8.36	7.3	4.6	335	7.3	.56	.027	7.3	1350	<2	100	<2	<2
	V	1914	8.46	7.7	4.8	352	8.4	.34	.018	5.3	760	<2	60	<2	<2
	C	1866	8.89	5.4	4.5	377	8.2	.54	.014	5.9	400	<2	<20	<2	<2
L-2A	V	4539	8.27	708	437	42.2	22	.49	5.13	16.3	240	2	4830	<2	17
	V	4736	8.20	714	434	42.2	22.9	.26	5.21	17.6	190	8	5210	<2	20
	C	4647	8.20	749	456	42.9	23.0	.088	5.26	18.4	60	<2	5290	2	9
B-3	V	3630	8.13	474	313	76.7	24.4	.22	.94	9.4	70	<2	1340	<2	7
	V	3519	8.24	471	313	76.9	24.2	.38	.94	9.3	80	<2	1310	<2	6
	C	1575	8.06	472	311	79.2	26.5	<.002	.10	15.0	40	<2	1390	<2	10
	C	3597	8.25	475	313	78.8	26.0	.029	.89	15.1	<30	<2	1490	<2	10

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* V is Vacuum, P is pressure, C is Cenrifuge

** ppm (mg/L)

*** ppb (mg/L)

Cu***	Li***	Mo***	Ni***	P**	Sr***	Ti***	V***	Zn***	Zr***	HCO3**	Cl**	SO4**	N**	F**	Br**	P-Ortho**	SIGMA
64	22	140	20	<.1	3560	42	15	21	<4	192	12.4	2140	1.7	<1	<1	<1	.01
259	24	148	<10	.1	3580	49	3	18	12	199	12.4	2160	3.5	1	1	<1	.01
55	29	150	20	.2	3540	41	23	140	13	207	13.2	2200	4.7	1	<1	<1	.04
51	24	160	<10	.1	3640	40	15	23	<4	207	12.8	2210	4.7	1	<1	<1	.26
65	37	160	30	.2	3560	47	36	9	26	201	12.7	2190	5.9	1	<1	<1	.07
68	280	<20	40	.2	5940	44	4	47	<4	1504	5.4	2690	6.3	13	.1	<1	-.75
66	300	<20	40	.2	5920	44	12	34	5	1630	5.1	2650	6.1	13	.1	<1	-.51
36	340	<20	10	<.1	5730	29	3	75	<4	1630	5.1	2670	9.8	13	<1	<1	-.28
49	290	<20	20	.2	6050	38	5	38	<4	1708	4.1	2650	10.0	13	<1	1	.08
50	290	<20	20	<.1	6050	39	6	30	<4	1698	4.8	2670	9.4	13	<1	<1	.13
49	290	<20	20	<.1	6010	40	1	38	<4	1669	4.6	2680	9.5	13	<1	<1	.01
107	57	30	50	.2	5300	60	30	29	15	623	13.4	2590	14.4	2	<1	<1	-.15
113	57	30	50	.3	5270	63	43	38	32	637	11.7	2600	13.8	1	<1	<1	.00
95	28	<20	<10	.2	5190	61	23	140	<4	576	15.0	2630	13.8	1	<1	<1	-.25
90	56	40	30	.2	5290	65	46	360	29	638	13.3	2580	14.4	1	<1	<1	-.71
110	66	50	60	.4	5360	70	61	20	45	586	11.5	2660	13.7	1	<1	<1	-.27
80	41	<20	10	.2	5680	59	24	10	<4	561	10.5	2670	14.6	1	<1	<1	-.31
95	55	<20	40	.1	5480	64	43	13	20	565	11.0	2670	14.7	1	<1	<1	-.62
71	25	<20	<10	.2	5100	59	10	18	<4	561	12.1	2420	13.0	1	<1	<1	-.20
83	32	<20	<10	.2	5400	82	18	18	<4	600	14.4	2620	14.0	1	<1	<1	-.25
30	240	<20	<60	<.1	1280	9	2	61	<4	576	9.1	1053	3.5	1	<1	<1	61
48	240	20	<10	<.1	1290	9	1	49	<4	630	9.5	1020	2.2	<1	<1	<1	-.97
60	240	<20	<10	<.1	1220	<1	<1	68	<4	615	7.1	1041	5.2	1	<1	<1	-.47
9	250	<20	<10	<.1	1290	4	5	8	<4	547	5.7	1102	6.1	1	<1	<1	.79
9	250	<20	<10	.1	1280	9	1	8	<4	576	5.1	1040	4.3	1	<1	<1	-.12
13	250	<20	<10	<.1	1290	9	<1	46	<4	576	5.7	1051	3.7	2			-.11
22	160	20	20	.1	1220	1	<1	87	<4	309	7.4	1156	46.6	3	<1	1	1.13
36	160	20	30	.2	1190	2	<1	45	<4	268	6.6	1129	40.8	2	<1	<1	-.79
18	180	20	<10	<.1	1300	<1	1	19	<4	293	7.9	1227	47.5	3	<1	<1	.11
12	180	<20	<10	<.1	1290	1	1	14	<4	325	5.4	1217	47.9	3	<1	<1	-.07
18	180	<20	20	<.1	1300	<1	1	12	<4	333	6.4	1205	48.3	3	<1	1	.33
50	73	<20	10	<.1	530	9	<1	75	<4	254	7.1	556	22.7	1	1	<1	1.6
35	83	<20	30	<.1	530	32	<1	49	<4	220	7.3	569	47.7	1	<1	<1	1.14
<2	83	<20	<10	.1	380	6	<1	150	<4	313	7.4	577	25.0	1	<1	1	-.76
11	85	<20	20	<.2	600	11	4	8	<4	278	3.9	598	28.3	1	<1	<1	-.63
8	83	<20	10	<.1	610	8	<1	<3	<4	278	4.2	602	28.7	1	<1	1	.23
8	81	<20	<10	.1	610	11	<1	9	<4	268	10.8	602	29.3	1	<1	<1	.51
9	83	20	<10	<.1	610	15	2	5	<4	283	4.0	593	26.9	1	<1	<1	-.04
7	83	<20	<10	<.1	610	10	<1	6	<4	283	4.4	597	29.0	1	<1	<1	-.07
57	72	<20	<10	<.1	390	64	<1	37	<4	293	9.8	456	15.3	1	<1	<1	.53
53	77	<20	<10	<.1	410	37	2	63	<4	293	10.5	470	15.9	1	<1	<1	-.72
5	75	<20	<10	<.1	460	9	<1	<3	<4	313	5.4	491	20.4	1	<1	<1	-.73
109	25	<20	110	.2	12300	67	26	173	<4	1254	24.3	2503	18.8	1	<1	1	.48
104	30	30	40	.1	12400	68	27	66	5	1141	23.0	2544	17.8	6	<1	1	-.27
90	24	20	20	.2	13100	67	16	43	<4	1288	22.2	2592	18.1	6	<1	1	-.20
69	43	<20	40	<.1	9760	50	13	50	<4	455	10.7	2190	8.5	<1	<1	<1	.36
67	41	<20	10	.2	9680	48	7	46	<4	447	9.3	2155	8.4	<1	<1	<1	-.48
53	44	<20	<10	<.1	9700	43	17	<3	<4	468	8.6	2150	9.5	<1	<1	<1	-.15
62	45	<20	10	<.1	9970	44	11	11	<4	496	8.3	2137	9.9	<1	<1	<1	-.27

TABLE 2 – CONCENTRATIONS OF CHEMICAL CONSTITUENTS PER 100g OF SOIL

Code	Method *	Ca**	Mg**	Na**	K**	Fe**	Mn**	SiO2**	Al***	Ag***	B***	Cd***
B5-1C	V	.65	.82	.23	.020	.00043	.00007	.0059	.19	<.001	1.08	.001
	V	.65	.82	.24	.020	.00190	.00007	.0063	.16	<.001	1.13	.001
	P	.66	.84	.25	.020	.00003	.00008	.0066	.11	.003	1.35	.001
	C	.66	.85	.25	.021	.00002	.00008	.0066	<.04	.002	1.12	.001
	C	.66	.84	.24	.021	.00003	.00008	.0067	.18	.007	1.22	.003
WD-3	V	1.03	.56	3.25	.034	.00072	.00232	.0143	.20	<.001	3.65	.002
	V	1.03	.56	3.30	.035	.00032	.00234	.0151	.17	.002	3.49	.002
	P	1.02	.56	3.33	.041	.00009	.00109	.0171	<.07	<.001	4.91	<.001
	C	1.06	.58	3.30	.036	.00009	.00242	.0153	<.07	<.001	3.65	<.001
	C	1.05	.57	3.32	.036	.00009	.00240	.0151	<.07	<.001	3.49	<.001
	C	1.04	.57	3.33	.036	.00009	.00238	.0149	<.07	<.001	3.33	<.001
E-5C	V	1.22	1.20	.26	.029	.00028	.00122	.0121	.39	.012	6.64	.004
	V	1.23	1.21	.26	.028	.00018	.00123	.0125	.29	.012	6.75	.002
	V 80ch 4 hr	1.23	1.20	.28	.030	.00020	.00073	.0126	.09	<.001	5.45	<.001
	P	1.23	1.22	.27	.029	.00010	.00131	.0134	.31	.010	7.88	.004
	C	1.24	1.22	.27	.030	.00006	.00127	.0125	.43	.018	6.88	.005
	C	1.24	1.22	.27	.030	.00008	.00125	.0120	.08	<.001	6.72	<.001
	C	1.25	1.22	.27	.030	.00005	.00124	.0126	.20	.008	6.80	.003
	C 2 HR	1.22	1.08	.26	.032	.00050	.00057	.0120	.31	<.001	4.52	<.001
	C 4 HR	1.22	1.19	.29	.031	.00080	.00074	.0134	.75	<.001	5.63	<.001
WD-4	V	.14	.26	1.79	.034	.00055	.00012	.0065	.08	<.001	.82	<.001
	V	.15	.26	1.82	.033	.00013	.00013	.0070	<.07	<.001	1.14	<.001
	P	.13	.25	1.82	.033	.00001	.00012	.0102	<.07	<.001	2.15	<.001
	C	.13	.26	1.82	.035	.00009	.00009	.0065	.10	<.001	.95	.003
	C	.13	.25	1.81	.035	.00020	.00010	.0068	.33	<.001	.88	<.001
	C	.13	.25	1.83	.035	.00036	.00010	.0077	.51	<.001	1.01	<.001
WD-40	V	.11	.22	1.73	.033	.00021	.00003	.0033	.10	<.001	.24	<.001
	V	.11	.22	1.70	.032	.00017	.00003	.0035	.10	<.001	.24	<.001
	C	.11	.23	1.84	.036	.00001	.00002	.0037	<.07	<.001	.24	<.001
	C	.11	.23	1.87	.036	<.00001	.00002	.0036	<.07	.002	.36	<.001
	C	.11	.23	1.85	.036	.00002	.00002	.0037	<.07	.007	.36	<.001
WD-1	V	.05	.05	1.92	.024	.00825	.00016	.0177	1.68	<.001	.42	<.001
	V	.05	.05	2.08	.025	.00176	.00005	.0107	3.14	<.001	.84	<.001
	P	.03	.04	2.10	.024	.00085	.00003	.0318	1.76	<.001	5.44	<.001
	C	.04	.06	2.07	.027	.00182	.00003	.0183	5.11	<.001	.31	.002
	C	.04	.06	2.05	.027	.00182	.00003	.0179	5.15	<.001	.52	<.001
	C	.04	.06	2.04	.027	.00182	.00003	.0179	5.24	<.001	.21	<.001
	C 8000RCF	.04	.06	2.03	.027	.00176	.00003	.0181	5.24	<.001	.21	<.001
	C 8000RCF	.04	.05	2.06	.027	.00176	.00003	.0181	5.24	<.001	.21	<.001
WD-1(2)	V	.04	.04	1.65	.021	.00340	.00011	.0137	5.65	<.001	1.05	<.001
	V	.04	.04	1.73	.024	.00206	.00007	.0100	3.18	<.001	.63	<.001
	C	.03	.04	1.85	.024	.00328	.00006	.0111	1.68	<.001	.21	<.001
E-2A	V	1.14	1.15	.05	.018	.00084	.00597	.0087	.28	.001	14.31	<.001
	V	1.14	1.14	.06	.019	.00045	.00616	.0094	.23	.003	15.45	<.001
	C	1.20	1.20	.06	.019	.00015	.00613	.0098	.07	.000	15.67	.001
8-3	V	.54	.59	.08	.014	.00027	.00078	.0036	.06	<.001	2.84	<.001
	V	.54	.59	.08	.014	.00047	.00078	.0035	.07	<.001	2.78	<.001
	C	.54	.59	.08	.016	.00001	.00025	.0057	.03	<.001	2.95	<.001
	C	.54	.59	.08	.015	.00004	.00074	.0058	<.01	<.001	3.16	<.001

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* V is Vacuum, P is Pressure Filtered, C is Centrifuged

** Meq/100g

*** Ueq/100g

Cr***	Cu***	Li***	Mo***	Ni***	Sr***	Ti***	V***	Zn***	Zr***	HCO3**	Cl**	SO4**	N**
.001	.036	.11	.06	.01	1.44	.031	.010	.013	<.003	.11	.012	1.59	.010
.007	.145	.12	.06	<.01	1.44	.036	.016	.010	.005	.12	.012	1.60	.010
.011	.031	.15	.06	.01	1.44	.030	.016	.076	.005	.12	.013	1.63	.012
.006	.029	.12	.06	<.01	1.48	.030	.010	.013	<.003	.12	.013	1.64	.012
.014	.036	.19	.06	.02	1.45	.035	.025	.005	.010	.12	.013	1.62	.015
.002	.063	2.38	<.01	.04	3.99	.054	.005	.042	<.003	1.45	.009	3.30	.027
.006	.061	2.55	<.01	.04	3.98	.054	.014	.031	.003	1.57	.008	3.25	.026
.005	.033	2.89	<.01	.01	3.85	.036	.003	.068	<.003	1.57	.008	3.28	.041
<.003	.045	2.46	<.01	.02	4.07	.047	.006	.034	<.003	1.65	.007	3.25	.042
<.003	.046	2.46	<.01	.02	4.07	.048	.007	.027	<.003	1.64	.008	3.28	.040
<.003	.045	2.46	<.01	.02	4.04	.049	.001	.034	<.003	1.61	.008	3.29	.040
.020	.070	.34	.01	.04	2.56	.052	.024	.019	.007	.42	.016	2.25	.043
.021	.074	.34	.01	.04	2.49	.055	.036	.024	.014	.43	.014	2.18	.041
.009	.070	.17	<.01	.03	2.46	.053	.019	.091	<.003	.41	.017	2.27	.041
.021	.059	.33	.02	.02	2.51	.056	.038	.228	.013	.43	.016	2.23	.043
.025	.072	.39	.02	.04	2.54	.061	.050	.013	.020	.40	.013	2.30	.041
.010	.052	.25	<.01	.01	2.69	.051	.020	.006	<.003	.38	.012	2.31	.043
.015	.062	.33	<.01	.03	2.60	.055	.035	.008	.009	.38	.013	2.31	.044
.007	.046	.15	<.01	<.01	2.41	.051	.008	.011	<.003	.40	.014	2.09	.041
.010	.054	.19	<.01	.02	2.56	.071	.018	.018	<.003	.38	.017	2.26	.039
<.003	.032	2.36	<.01	<.01	1.00	.013	.003	.064	<.003	.64	.018	1.50	.017
<.003	.052	2.36	.01	<.01	1.00	.013	.001	.051	<.003	.70	.018	1.45	.011
<.003	.064	2.36	<.01	<.01	.95	<.001	<.001	.071	<.003	.69	.014	1.48	.025
.005	.010	2.46:	<.01	<.01	1.00	.006	.007	.008	<.003	.61	.011	1.57	.030
.005	.010	2.46:	<.01	<.01	1.00	.013	.001	.008	<.003	.64	.010	1.48	.021
<.003	.014	2.46:	<.01	<.01	1.00	.013	<.001	.048	<.003	.64	.011	1.49	.018
.003	.023	1.50	.01	.02	.91	.001	<.001	.087	<.003	.33	.014	1.57	.217
.005	.037	1.50	.01	.03	.89	.003	<.001	.045	<.003	.29	.012	1.53	.190
.003	.018	1.69	.01	<.01	.97	<.001	.001	.019	<.003	.31	.015	1.67	.221
<.003	.012	1.69	<.01	<.01	.96	.001	.001	.014	<.003	.35	.010	1.65	.223
<.003	.018	1.69	<.01	.02	.97	<.001	.001	.012	<.003	.36	.012	1.64	.225
<.002	.089	1.19	<.02	.02	.68	.021	<.001	.130	<.005	.47	.023	1.31	.183
<.002	.062	1.35	<.02	.06	.68	.075	<.001	.085	<.005	.41	.023	1.34	.385
<.002	<.002	1.35	<.02	<.01	.49	.014	<.001	.259	<.005	.58	.024	1.36	.202
<.002	.020	1.38	<.02	.04	.77	.026	.009	.014	<.005	.51	.012	1.41	.228
<.002	.014	1.35	<.02	.02	.79	.019	<.001	<.005	<.005	.51	.013	1.42	.232
<.002	.014	1.32	<.02	<.02	.79	.026	<.001	.016	<.005	.50	.034	1.42	.236
<.002	.016	1.35	.02	<.02	.79	.035	.004	.009	<.005	.52	.000	1.40	.217
<.002	.012	1.35	<.02	<.02	.79	.024	<.001	.010	<.005	.52	.014	1.41	.234
<.002	.101	1.17	<.02	<.02	.50	.151	<.001	.064	<.005	.54	.031	1.07	.124
<.002	.094	1.25	<.02	<.02	.51	.087	.004	.109	<.005	.54	.033	1.11	.128
<.002	.009	1.22	<.02	<.02	.59	.021	<.001	<.005	<.005	.58	.017	1.16	.165
.011	.054	.11	<.01	.06	4.48	.044	.016	.080	<.003	.65	.022	1.67	.043
.012	.052	.14	.01	.02	4.51	.045	.017	.032	.002	.64	.021	1.70	.044
.006	.045	.11	.01	.01	4.78	.045	.010	.021	<.003	.68	.020	1.73	.047
.003	.025	.14	<.01	.02	2.55	.025	.006	.018	<.001	.17	.007	1.04	.014
.003	.024	.14	<.01	<.01	2.53	.023	.003	.016	<.001	.17	.006	1.03	.014
.004	.019	.15	<.01	<.01	2.54	.021	.008	<.001	<.001	.18	.006	1.03	.016
.004	.022	.15	<.01	<.01	2.61	.021	.005	.004	<.001	.19	.005	1.02	.016

TABLE 3 COMPARISON OF COMMERICAL LAB RESULTS TO MBMG RESULTS

CODE	METHOD*	CA**		MG**		NA**		SO4**	
		COMMERCIAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB
BS-1C	V	.63	.65	.89	.82	.25	.24	0	1.60
	P		.66		.84		.25		1.63
	C		.66		.84		.24		1.63
WD-3	V	.49	1.03	.31	.56	3.31	3.28	3.28	3.28
	P		1.02		.56		3.33		3.28
	C		1.05		.57		3.32		3.27
E-5C	V	1.01	1.23	1.09	1.21	.27	.26	2.31	2.21
	P		1.23		1.22		.27		2.23
	C		1.24		1.22		.27		2.31
WD-4	V	.11	.15	.18	.26	1.73	1.81	1.73	1.48
	P		.13		.25		1.82		1.48
	C		.13		.25		1.82		1.51
WD-4D	V	.10	.11	.17	.22	1.97	1.72	1.63	1.55
	C		.11		.23		1.85		1.65
WD-1	V	.07	.05	.07	.05	2.06	2.00	1.42	1.32
	P		.03		.04		2.10		1.36
	C		.04		.06		2.05		1.41
WD-1(2)	V		.04		.04		1.69		1.09
	C		.03		.04		1.85		1.16
E-2A	V	1.24	1.14	1.25	1.15	.10	.06	2.06	1.69
	C		1.20		1.20		.06		1.73
B-3	V	.46	.54	.56	.59	.11	.08	.97	1.04
	C		.54		.59		.08		1.03

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* V IS VACUUM
*P IS PRESSURE
*C IS CENTRIFUGE
** Meq/100g

TABLE 4

		% RELATIVE STANDARD DEVIATION (PPM)								Average
CODE	METHOD*	Ca	Mg	Na	K	Mn	SiO_2	HCO_3	SO_4	Absolute Sigma***
B5-1C	V	.2	<.2	.4	1.6	2	5	2.5	.6	.01
	C	.4	.2	.9	<.1	2	1	2.1	.6	.16
WD-3	V	.2	<.1	1.1	1.5	1	1	5.7	1.1	.63
	C	.8	.8	.4	.8	1	1	1.2	.6	.07
E-5C	V	.2	.6	1.0	.8	2	2.0	1.6	.3	.08
	C	.7	.2	.7	1.1	1	2.4	.7	.2	.40
WD-4	V	7.2	<.1	1.3	1.1	5	5.9	6.3	2.3	.79
	C	.5	.7	.6	1.1	3	9.2	3	3.1	.34
WD-4D	V	1.2	1.0	1.4	.5	11	4.5	10	1.7	.96
	C	.6	.5	.6	.5	8	1.8	6.7	.9	.17
WD-1	V	6.8	1.2	5.7	4.9	76	34.4	10.3	1.6	1.37
	C	<.1	.8	.8	1.0	7	.8	2.2	.6	.30
WD-1(2)	V	3.7	3.0	3.5	11	28	22.2	3.6	2.1	.62
	C**									
E-2A	V	.6	.5	<.1	2.8	2	16	6.6	3.9	.38
	C**									
B-3	V	.4	<.1	.1	.6	<1	9.6	1.3	1.1	.42
	C	.4	.4	.4	1.5	70	.5	4.1	.4	.21

* V IS VACUUM
* C IS CENTRIFUGE
**Due to sample shortages only one sample prepared

TABLE 5 LABORATORY OBSERVATION OF EXTRACTION METHODS

Code	Method	Sample Vol.	Trap Vol.	Min/ Sample	Effective Min/Sample
B5-1C	V	44	2.8	210	15
	V	43	3.2		
	P	28		210	15
	C	55		10	3
	C	50			
WD-3	V	45	<.5	120	15
	V	53	<.5		
	P	24		120	15
	C	65		8	3
	C	68			
	C	60			
E-5C	V	49	1.2	210	15
	V	50	2.8		
	V 4 HR. 80 cb	25	4	240	20
	P	33		180	15
	C	70		8	3
	C	75			
	C	82			
	C 2 HR	10		15	5
	C 4 HR	10		15	5
WD-4	V	23	<.5	210	15
	V	29	<.5		
	P	22		180	15
	C	45		8	3
	C	40			
	C	48			
WD-4D	V	27.5	<.5	240	15
	V	32	<.5		
	C	38		3	3
	C	40			
	C	40			
WD-1	V	16.5	<.5	360	20
	V	13.5	<.5		
	P	17		360	15
	C	28		8	3
	C	30			
	C	25			
	C*8000RCF	33		8	3
	C*8000RCF	35			
WD-1(2)	V	36	<.5	240	15
	V	42	<.5		
	C	35		20	5
E-2A	V	13	.8	480	25
	V	14	2.1		
	C	18		90	20
B-3	V	45	<.5	240	15
	V	55	<.5		
	C	68		10	3
	C	65			

TABLE 6 PARTICAL SIZE ANALYSIS

CODE	% SAND		% SILT		% CLAY		% SATURATION	
	ENERGY LAB	MSU LAB	ENERGY LAB	MSU LAB	ENERGY LAB	MSU LAB	ENERGY LAB	MBMG LAB
BS-1C	65	58.9	23	24	12	17.1	28.3	35.6
WD-3	54	61.6	30	21.3	16	17.1	60.2	58.9
E-5C	35	32.9	44	32	21	35.1	38.3	41.5
WD-4	33	36.9	47	32	20	31.1	54.8	68.2
WD-4D	13	64.9	53	16	34	19.1	67.8	65.2
WD-1	67	21.6	20	45.3	13	33.1	81.8	113
E-2A	43	56.9	35	22	22	21.1	38.7	32
B-3	51	60.9	37	24	12	15.1	32.2	22.9

TABLE 7 COMPARISON OF RESULTS FROM TWO LABS BY METHOD OF EXTRACTION

CODE	METHOD*	CA**		MG**		NA**		SO4**	
		COMMERICAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB	COMMERICAL LAB	MBMG LAB
BS-1C	V	22.1	18.1	31.3	23.2	8.69	6.72	60.4	44.6
	P		18.6		23.7		6.96		45.8
	C		18.5		23.7		6.87		45.8
WD-3	V	8.09	17.4	5.21	9.54	55.0	55.7	54.5	55.6
	P		17.3		9.54		56.6		55.6
	C		17.8		9.71		56.4		55.5
E-5C	V	26.5	29.5	28.5	29.0	6.95	6.31	60.3	54.0
	P		29.7		29.4		6.55		53.7
	C		30.0		29.3		6.52		55.5
WD-4	V	2.04	2.14	3.35	3.78	31.6	26.6	31.6	21.6
	P		1.90		3.65		26.6		21.7
	C		1.92		3.74		26.7		22.2
WD-4D	V	1.46	1.65	2.53	3.36	29.0	26.5	24.0	23.8
	C		1.68		3.53		26.7		25.3
WD-1	V	.80	.42	.84	.48	25.2	17.8	17.4	11.7
	P		.29		.36		18.6		12.0
	C		.33		.49		18.2		12.5
WD-1(2)	V		.37		.39		15.0		9.6
	C		.27		.37		16.5		10.2
E-2A	V	32.0	21.7	32.3	35.8	2.66	1.8	53.0	52.5
	C		22.8		37.5		1.8		54.0
B-3	V	14.2	15.6	17.3	25.7	3.27	3.3	30.0	45.2
	C		15.6		25.7		3.4		44.6

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* V IS VACUUM
* P IS PRESSURE
* C IS CENTRIFUGE
** Meq/L